Using observatory, differential magnetometer and magneto-telluric data for modelling geomagnetically induced currents in Spain

J Miquel Torta, Santi Marsal, Juan J Curto, Oscar Cid, Juanjo Ledo, Alex Marcuello, Pilar Queralt, Anna Martí, Joan Campanyà

The lessons learnt from all our analyses on the threat posed by geomagnetically induced currents (GICs) to the Spanish 400 kV power grid are used in a new project for establishing a series of local MT surveys to properly map the geoelectric field, enabling the matching between the model predictions and actual GIC measurements across the entire Spanish territory. The number of GIC measurements are also planned to be increased by indirectly obtaining them with the deployment of magnetometers under some selected power lines, in contrast with the more usual way of measuring the current in the neutrals of the transformers at substations, and thus avoiding the necessity of interfering with the power companies.

The modelling of GICs in Spain was started by taking the plane wave assumption for the external current source, an homogeneous Earth conductivity for the induction problem, and the Lehtinen and Pirjola method for the engineering problem (Torta et al., 2014). We also used 1-D depth-conductivity models, but they did not perform substantially better than the homogenous Earth approach. To improve the first model, in Torta et al. (2017) we interpolated the geomagnetic variations from the records of several observatories with the Spherical Elementary Current Systems (SECS) technique. We also performed magneto-telluric (MT) measurements in the vicinity of the substation from which we have GIC measurements and showed that the regional geoelectrical response is strongly affected by the Mediterranean Sea. In that case, a high model accuracy was obtained when using the empirical surface impedance, adopting either a 2-D approach or the full impedance tensor.

To continue developing modelling improvements, we have just started with a new project aimed at addressing the characterization of GICs in the Iberian Peninsula by means of a multidisciplinary approach. We first plan to characterize the magnetospheric and ionospheric sources that generate the greatest GICs. To do that, we will exploit our recent experience on the use of SECS to map the polar current systems associated with the geomagnetic sudden commencements on the St. Patrick's Day storms (Marsal et al., 2017). To characterize the internal sources, we will define a geoelectric model by integrating previous MT soundings and new data to determine how the 3D structure of the subsurface resistivity affects the GICs. Finally, new GIC intensities at critical locations will be obtained by differential magnetometry (the GIC is estimated from the difference between the variations of the magnetic field recorded under a power line, and the same variations but recorded some distance away, where the magnetic field of the GIC has no effect). We will deploy several stations across the country, measuring GICs under different power lines during several weeks or months. We have already installed a couple of magnetometers under a 400 kV line close to Ebre observatory. To detect the GIC effects, we first found the orientation angles, the scale values and the bias fields by minimizing the vector of residuals from a least squares fit to the one-minute data recorded at both places during the quietest days. Then, we rotated those residuals to the directions parallel and perpendicular to the power line, and obtained the induced current from Biot-Savart law, according to the line wire-to-wire distance, their height and the distance of the magnetometer from them. Figure 1 displays the GIC signal obtained for one of the very few slightly disturbed days during the last season. It correlates reasonably well with that obtained with our model for the same line.

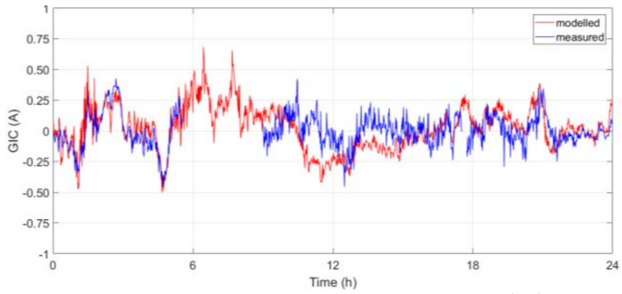

Figure 1: GIC measured and modelled signals obtained for 18/06/2018.

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Author:

J.M. Torta[1], S. Marsal[1], J.J. Curto[1], O. Cid[1], J. Ledo[2], A. Marcuello[2], P. Queralt[2], A. Martí[2], J. Campanyà[3]

1) Observatori de l'Ebre, (OE), CSIC - Univ. Ramon Llull, Roquetes, Spain

2) Institut Geomodels, Universitat de Barcelona, Barcelona, Spain

3) School of Physics, Trinity College Dublin, Ireland

Corresponding author:

Joan Miquel Torta

Observatori de l'Ebre

Horta Alta, 38, 43520 Roquetes, Spain

Tel.: +34 977500511

e-mail: jmtorta@obsebre.es